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[A I Okegbade](#) * and [Abiola Opeyemi Egbewumi](#) *

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Article

Time Series Modeling of Livebirths and Stillbirths: A Case Study of Obafemi Awolowo University Teaching Hospital Complex, Ile-Ife

Okegbade A.I. * and Egbewumi A.O. *

Department of Statistics, Ladoké Akintola University of Technology, Ogbomosho, Nigeria

* Correspondence: aiokegbade@lautech.edu.ng (Q.A.I.); egbewumiabiola1@gmail.com (E.A.O.)

Abstract

Live births and stillbirths are key public health indicators, with significant social and economic consequences. This study applies time series modeling to the quarterly data of livebirths and stillbirths recorded at Obafemi Awolowo University Teaching Hospital Complex (OAUTHC), Ile-Ife, from 2001 to 2020. Using Augmented Dickey-Fuller tests, the data were confirmed to be stationary. Appropriate ARMA models ARMA(2,3) for livebirths and ARMA(1,3) for stillbirths were fitted based on minimum values of AIC, BIC, and HQIC. Forecasts indicate a sharp increase in livebirths between 2021 and 2023, with a relatively stable trend in stillbirths. These findings underscore the importance of continuous improvement in maternal healthcare and data-driven planning.

Keywords: livebirths; stillbirths; ARMA models; time series; forecasting; Nigeria; hospital records

1. Introduction

Childbirth is a critical indicator in global public health monitoring. It can result in either livebirths or stillbirths, both of which carry health system implications. In Nigeria, a high burden of stillbirth persists despite advances in maternal healthcare. With a stillbirth rate of over 40 per 1,000 births in recent years, data-driven approaches are vital to understanding and curbing this trend. This study investigates the pattern of livebirths and stillbirths over a 20-year period using time series models, with the goal of providing reliable forecasts and informing policy interventions at OAUTHC, Ile-Ife.

2. Literature Review

Previous studies have identified multiple maternal, fetal, and environmental risk factors contributing to stillbirths (Odendaal et al., 2021; Malacova et al., 2018). Moreover, the World Health Organization emphasizes the use of accurate and complete data in evaluating maternal health interventions. Time series methods, particularly ARIMA-based models, have been widely used in medical forecasting due to their robustness in handling temporal patterns (Box & Jenkins, 1976).

3. Methodology

3.1. Data Source

Quarterly data from 2001 to 2020 were obtained from the Health Information Management Department, OAUTHC, Ile-Ife.

3.2. Model Selection Process

Stationarity Test: Augmented Dickey-Fuller (ADF) test was used to confirm stationarity.

Model Identification: ACF and PACF plots helped suggest potential ARMA models.
Model Selection: Models were compared using Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Hannan-Quinn Criterion (HQIC).
Diagnostic Checks: Residual plots and normality tests were used to confirm model adequacy.

3.3. Software Tools

Data analysis was conducted using Microsoft Excel and GRETL software.

4. Results

4.1. Livebirths

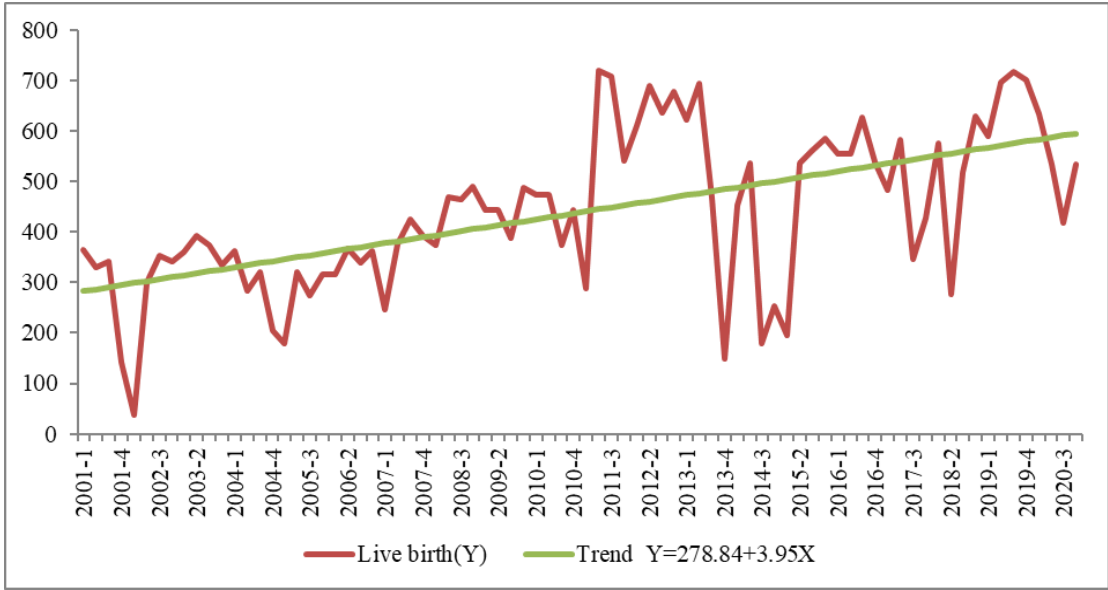


Figure 1. Shows an upward linear trend of livebirth was observed over the 20-year period.

Test of Stationary for live birth of the original data from 2001 to 2020
The test of stationary is done by using Augmented Dickey Fuller test

H₀: The series is not stationary
H₁: The series is stationary

Test Statistic: $\alpha = 0.05$

Table 1. Result for Augmented Dickey Fuller (ADF) test at original Level .

Dickey fuller	-0.352922
P-value	0.001950

Decision Rule: Reject H₀ if p value is less than 0.05 otherwise do not reject H₀
Decision: Since the p-value is less than 0.05 the null hypothesis is therefore rejected
Conclusion: Hence the mean and variance of time series is constant in the whole series which implies that there is no presence of unit root in the series indicating stationarity.

Model Identification

To get an appropriate time series model, the smallest value of the Akaike (AIC), Schwarz, and Hannan Quinn Criterion of the identified model is selected.

Table 2: reveals that out of the three criterions Akaike, and Hannah-quinn Criterion has the smallest value in ARMA(2,3) compare to the other models, indicating that ARMA(2,3) is the best model.

Table 2. Result for Model Identification using ARMA (p,q) for live birth.

S/N	Model	Akaike Criterion	Schwarz Criterion	Hannan Quinn Criterion
1.	ARMA(1,1)	996.8713	1006.399	1000.691
2.	ARMA(1,2)	997.7951	1009.705	1002.570
3.	ARMA(1,3)	997.0495	1011.342	1002.780
4.	ARMA(1,4)	997.1770	1013.851	1003.862
5.	ARIMA(2,1)	998.4753	1010.385	1003.250
6.	ARIMA(2,2)	998.7319	1013.024	1004.462
7.	ARMA(2,3)	990.1766	1006.851	996.8618
8.	ARMA(2,4)	992.0821	1011.138	999.7223
9.	ARIMA(3,1)	997.8235	1012.116	1003.554
10.	ARMA(3,2)	999.8183	1016.493	1006.503
11.	ARMA(3,3)	992.0782	1011.134	999.7184
12.	ARMA(3,4)	992.3840	1013.822	1000.979
13.	ARMA(4,1)	999.8184	1016.493	1006.504
14.	ARMA(4,2)	992.8446	1011.901	1000.485
15.	ARMA(4,3)	994.0780	1015.516	1002.673
16.	ARMA(4,4)	993.1728	1016.993	1002.723

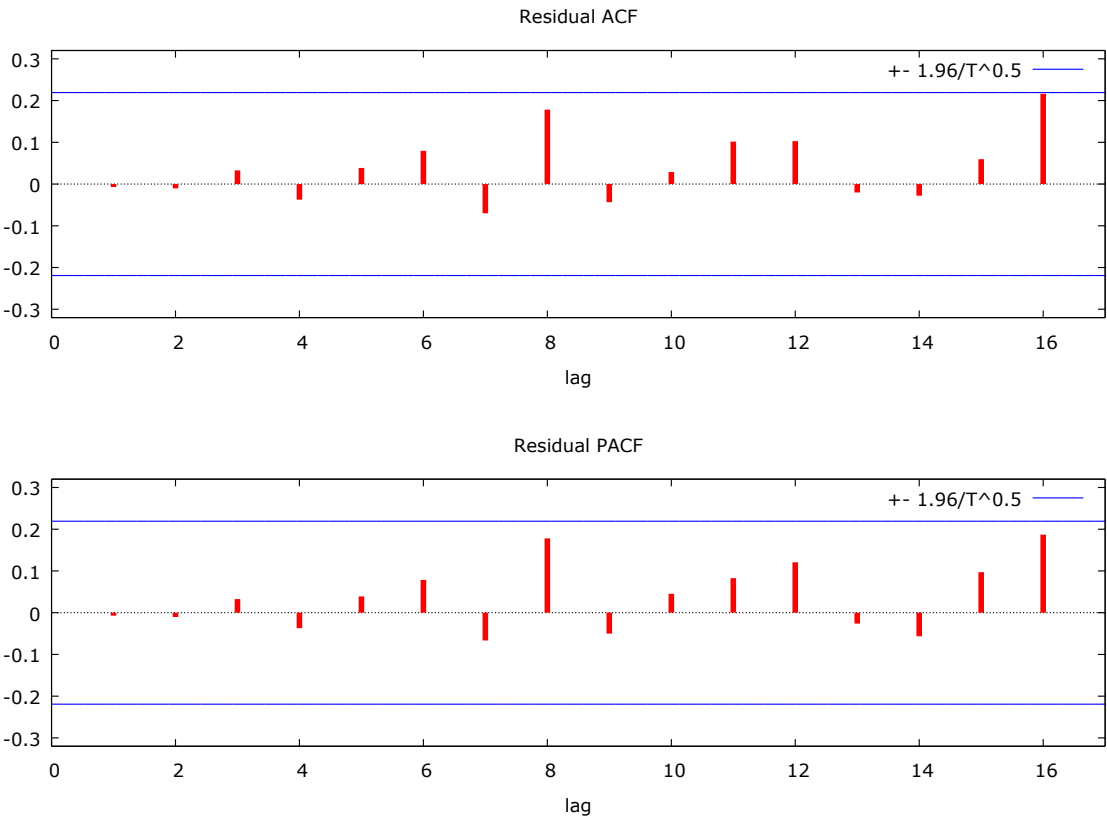


Figure 2. shows that the residual ACF and PACF value at lag 1 to lag 16 hover around zero line, this made the model valid and adequate.

Table 3. Result for the Forecast of Live birth from 2021 to 2023.

Observation	Prediction	std. Error	95% Interval
2021:1	445.584	104.061	(241.628, 649.540)
2021:2	343.792	112.902	(122.508, 565.076)
2021:3	325.178	115.072	(99.6402, 550.716)
2021:4	337.374	124.964	(92.4492, 582.299)
2022:1	369.199	137.392	(99.9154, 638.483)
2022:2	408.186	146.375	(121.297, 695.075)
2022:3	443.702	150.379	(148.964, 738.440)
2022:4	468.810	151.146	(172.570, 765.050)
2023:1	480.793	151.161	(184.523, 777.063)
2023:2	480.597	151.831	(183.013, 778.181)
2023:3	471.614	153.125	(171.495, 771.732)
2023:4	458.255	154.363	(155.709, 760.801)

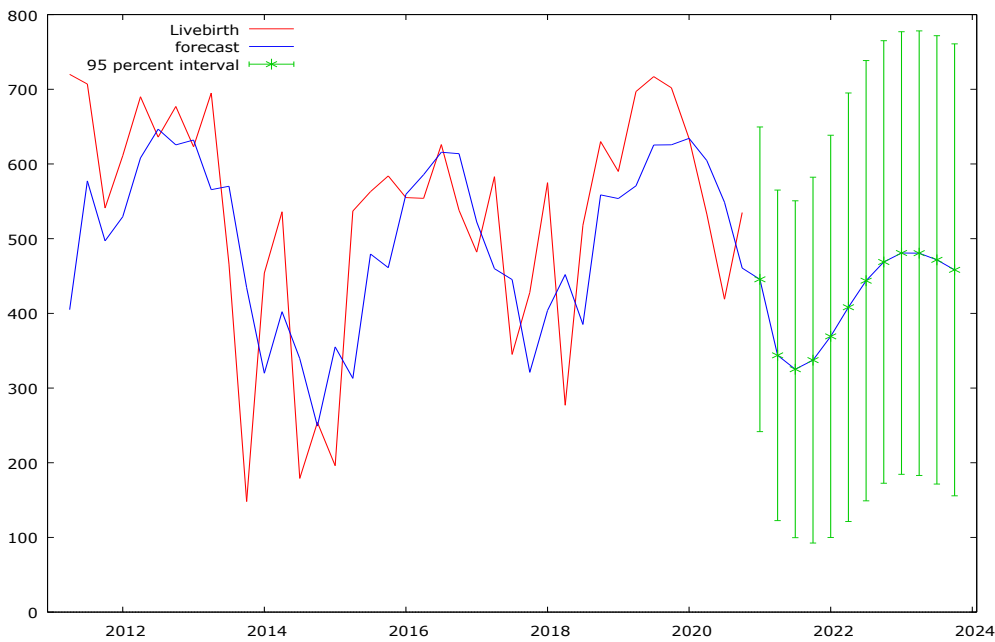


Figure 4. shows the forecast from 2021 to 2023 which predicted a sharp increase in livebirths, reaching a quarterly average of approximately 480 by 2023.

4.2. Stillbirths

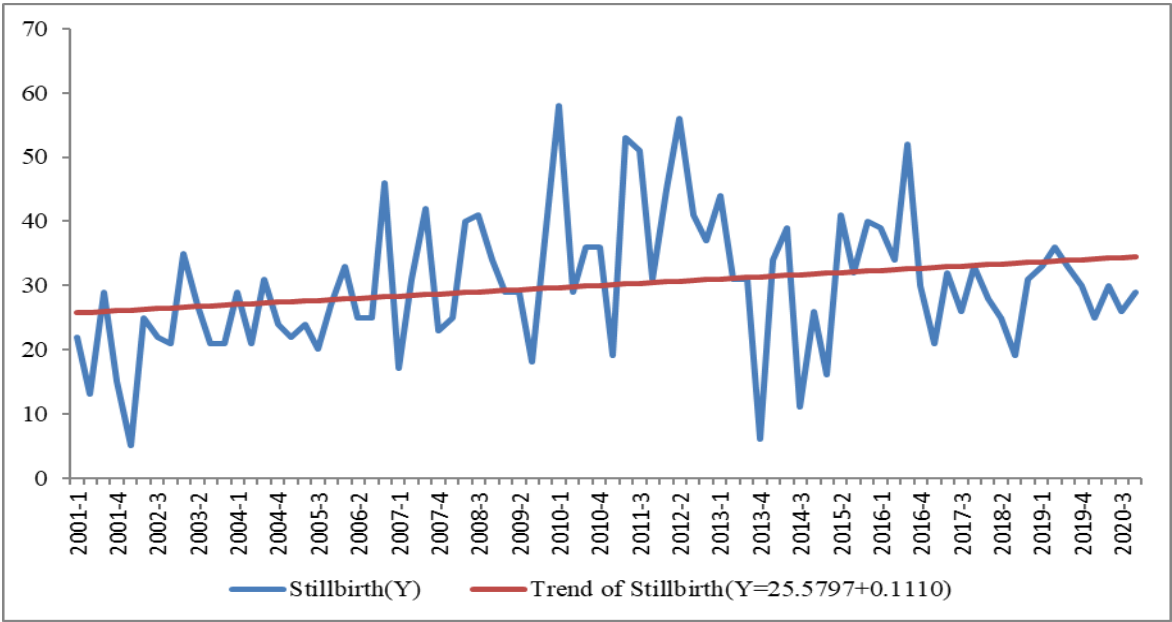


Figure 5. Shows a linear increasing trend of stillbirths, less pronounced than livebirths.

Table 4. Result for Augumented Dickey Fuller (ADF) test at Original Level of number of stillbirth.

Dickey fuller	-0.765746
P-value	1.609e-007

Decision Rule: Reject Ho if p value is less than 0.05 otherwise do not reject Ho
Decision: Since the p-value is less than 0.05 the null hypothesis is therefore rejected
Conclusion: Hence the mean and variance of time series is constant in the whole series indicating stationarity.

4.2.1. Model Identification

To get an appropriate time series model, the smallest value of the Akaike, Schwarz, and Hannan Quinn Criterion of the identified model is selected.

Table 5: reveals clearly that out of the three criterions Akaike, and Hannah-quinn Criterion was found to be the smallest value in ARMA(1,3) compare to the other models, so the best model is ARMA(1,3).

Table 5. Result for model identification ARMA (p,q) for number of Stillbirth.

S/N	Model	Akaike Criterion	Schwarz Criterion	Hannan-Quinn Criterion
1.	ARMA(1,1)	600.6147	610.1428	604.4348
2	ARMA(1,2)	602.6021	614.5122	607.3772
3	ARMA(1,3)	597.7584	612.0506	603.4885
4	ARMA(1,4)	599.0405	615.7147	605.7257
5	ARMA(2,1)	602.6082	614.5183	607.3833
6	ARMA(2,2)	599.5910	613.8832	605.3212
7	ARMA(2,3)	598.3764	615.0506	605.0616
8	ARIMA(2,4)	600.3763	619.4325	608.0165
9	ARMA(3,1)	598.1364	612.4286	603.8666
10	ARMA(3,2)	598.2832	614.9574	604.9683
11	ARMA(3,3)	600.2506	619.3069	607.8908
12	ARMA(3,4)	602.2506	623.6889	610.8458

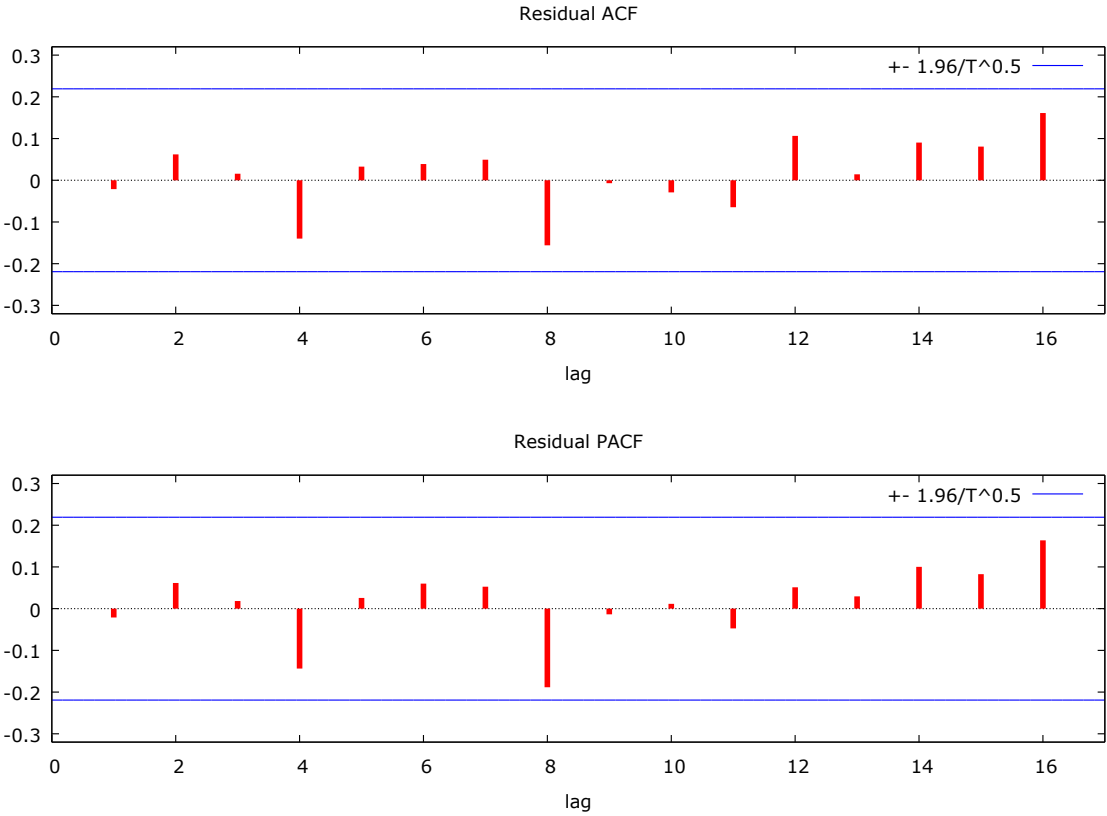


Figure 6. Residual ACF and PACF of the Best ARIMA Model for Stillbirth.

Figure 6: shows residual ACF and PACF value at lag 1 to lag 16 hover around zero line, this made the model valid and adequate.

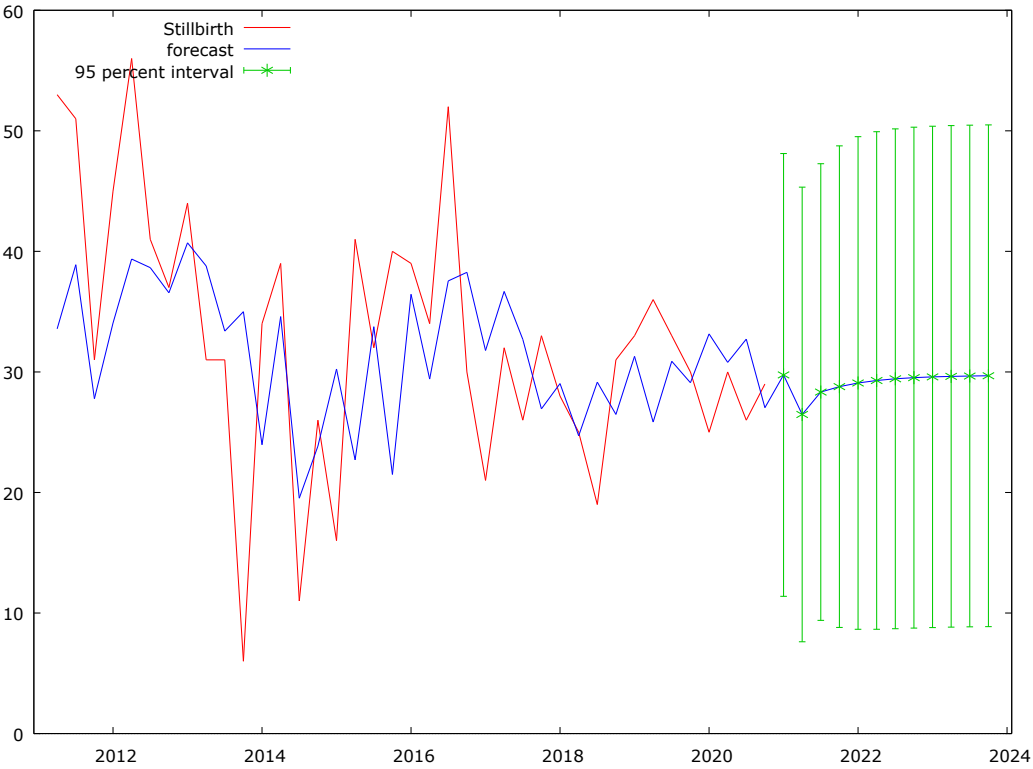


Table 6 and Figure 7 shows forecast from 2021 to 2023 predicted that stillbirths is expected to remain relatively stable, with minor fluctuations.

Table 6. Result for the Stillbirth Forecast from year 2021 to 2023.

Observation	Prediction	std. Error	95% Interval
2021:1	29.7517	9.37009	(11.3867, 48.1168)
2021:2	26.4700	9.62007	(7.61505, 45.3250)
2021:3	28.3299	9.66421	(9.38836, 47.2714)
2021:4	28.7793	10.1915	(8.80434, 48.7544)
2022:1	29.0838	10.4245	(8.65212, 49.5155)
2022:2	29.2900	10.5297	(8.65220, 49.9278)
2022:3	29.4297	10.5776	(8.69799, 50.1614)
2022:4	29.5243	10.5995	(8.74967, 50.2989)
2023:1	29.5884	10.6095	(8.79408, 50.3827)
2023:2	29.6318	10.6141	(8.82847, 50.4351)
2023:3	29.6612	10.6162	(8.85374, 50.4686)
2023:4	29.6811	10.6172	(8.87175, 50.4904)

5. Discussion

The upward trend in livebirths and the stabilization of stillbirths may reflect improvements in healthcare delivery, particularly antenatal and intrapartum services at OAUTHC. These findings support global calls for investment in maternal health infrastructure and skilled birth attendance.

6. Conclusion and Recommendations

The ARMA models provided a good fit for the birth data and were effective in forecasting future values. The hospital management is encouraged to:

- Continue improving maternal health services
- Promote facility-based delivery
- Monitor and evaluate interventions using hospital data

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